DESIGN, CONSTRUCTION, TESTING, AND EVALUATION OF WATER TROUGH FLOAT VALVES

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ABSTRACT

The following report outlines the design, construction, testing, and evaluation of water trough float valves. A corrosion resistant material called Delrin® was used to construct three different style float valves. The Delrin® valves were constructed to replace the current dairy standard brass valves. The first design was completed using water pressure to help form a seal. This was done by rotating the fixed link from the bottom of the valve by the outlet to the top of the valve. The plunger contained a Nitrile seal as the main seal and an o-ring as a backflow seal. The second design contained a plunger with two o-rings. One o-ring was used as the main seal and the other as the backflow seal. This design featured a large outlet and had a traditional underside fixed link to allow sealing against water pressure. The third design was similar to the second design however it used several small outlets to replace the one large outlet.

The first float valve design failed in testing because it caused significant water hammer as the valve closed. The style was abandoned and the second design was tested next. The second design also failed in testing because the main sealing o-ring would squeeze out the outlet when attempting to seal. The third and final design was successful and several of them were installed at a dairy in Hanford, CA.

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INTRODUCTION

Background/ Justification

The current standard for water trough float valves in dairies throughout California is the Control Devices, LLC R400 series BOB® brass float valve. The valves work very well for a while, but after some time the brass becomes pitted and the valves leak so that the troughs overflow. Dairymen will replace the seals in the valves causing them to function properly for a short time, but the pitted brass remains a problem. For many dairymen it is not worth the time and effort to replace the seals because the valve will leak again so soon. Other dairymen will replace the seals once, and replace the entire valve the next time there is a problem. The valves are fairly expensive to replace, so there is a need for improvement in the design of water trough float valves. The price of a float valve versus the life expectancy is less than ideal. There is a need for either a float valve that costs less, or one that lasts much longer with less maintenance.

Objectives

The goal of this project is to design and build a float valve that works similarly to a BOB® float valve with a material that is corrosion resistant. A Delrin® float valve is to be designed and constructed to replace the current brass float valves and attempt to resolve the issue of short life span. Also, as an alternative to the skirt seals used in the BOB® valves, simple o-rings will be used to prevent backflow. Several Delrin® valves will be constructed and installed at a diary in the San Joaquin Valley of California in order to determine proper function and greater life expectancy. The new Delrin® float valves should have a lower cost than the brass BOB® valves and the replacement of seals should be simple and cheap.

LITERATURE REVIEW

A search was conducted in order to find factors that cause or contribute to the pitting and corrosion of brass. Also, different types of float valves and options to fix the existing brass float valves were researched in order to check compatibility with use in the dairy industry. Finally, materials and design procedures were researched in order to properly design the new valves.

Currently the standard float valve used in the dairy industry is Control Device's (2012) R400 series BOB® float valve made from heavy duty cast brass. It features two male NPT ends that vary in size depending on need and application, various flow rates at various pressures, and a cast plunger with Nitrile seals. These valves are relatively light weight and cost around $50.00. They are widely available at dairy supply stores throughout the San Joaquin Valley of California. The Nitrile seal at the end of the plunger is pushed forward into a polished brass seat inside the valve body. The seal seats against the direction of the flow of water. The other skirt seal is used to prevent backflow of water. A photograph of the BOB® float valve can be seen in Figure 1 below.

Figure 1. ¾ in. BOB® float valve.

A study of corrosion in brass revealed that when in connection with galvanized pipe, brass corrodes uniformly and at an accelerated rate. Also, hot water increases the leaching of lead from brass which causes pitting (Sarver, 2011). For a dairy in California's San Joaquin Valley, it is possible that the water would heat up in the summer time if stagnate for only a short time. Hot water in combination with galvanized pipe is very likely to be a problem and diaries are all equipped with galvanized water pipes in California. A float valve connected to galvanized pipe can be seen in Figure 2 below.

Figure 2. Float valve in contact with galvanized pipe.

A study in the journal Corrosion Science showed that the presence of natural organic matter in water causes leaching of metals from the surface of brass (Korshkin, 2000). This leaching of metals is a type of corrosion to cause pitting which destroys the capability of the valve to seal properly. Water at dairies is not treated and organic matter is prevalent in troughs where the brass float valves are used.

The effect of different pH levels on the corrosion of brass was evaluated when in the presence of copper and ammonia-sulphate. At a pH of around 7.2, the brass corrodes at a higher rate. The pH of trough water at dairies is uncontrolled and unmonitored, however 7.2 is fairly neutral and possible for a trough (Forthy, 1962). In water that is more acidic, zinc in brass is corroded away, while basic water causes corrosion of the lead in brass. Once material around the valve seat has become corroded, the plunger seal may still seat, but the velocity of the water just before it arrives at the piston and seat may be much higher causing the plunger to be met with more resistance. This could cause a valve to fail much sooner, and before corrosion severely damages any parts in the valve.

In an interview with Jimmy Goebel, a dairy manager in Hanford, California, it became clear that the BOB float valves are unsatisfactory. The valves work well for a short time before corrosion, wear, and poor seals cause them to leak. The Nitrile seal at the end of the plunger becomes crushed and deformed by the seat over time. Also, the skirt seals shrink and allow water to backflow through the valve body freely. The leaky float valves cause water troughs to overflow and this costs dairymen time and money (Goebel, 2012). Following an inquiry of submerged float valves, Mr. Goebel stated that in the California dairy industry, float valves must be two times the diameter of the valve above the water surface (ie. a ¾ in. valve must be 1-1/2 in. above the water surface) to prevent harmful water back flowing into the pipes. The water trough setup can be seen below in Figure 3.

Figure 3. New float valve in use at Jimmy Goebel's dairy.

John Fischer, an engineering lab technician at Zurn Wilkins, discussed possible improvements to the current float valves used by dairymen. The current float valves have a small brass fillet for the valve seat. A new seat with a larger seating surface could be made from other types of metal such as stainless steel and pressed into the valves body. This would decrease the corrosion in the area of the valve seat causing the water velocity at the plunger to be much lower, making it easier for the rubber to make a seal with the seat. Another option for fixing the existing float valves would be a polyethylene seat. For this option to be possible, small tabs may be extended to the end of the valve and heated and formed around the end to hold the seat in place. A final option would be to make the valve fully out of another material such as PVC or Delrin® (Fischer 2013).

PROCEDURES AND METHODS

Design Procedure

The first step in the re-design of water trough float valves was to determine the proper material to use. Many corrosion-resistant materials were analyzed including stainless steel, PVC, Delrin® and other plastics. It was determined that Delrin® was the best choice for the purpose of a low production product due to its strength, wear properties, and ease of machining. In a mass production setting, another type of acetal resin would be appropriate. Injection moldings can be made at a fairly low cost using Black Acetal Copolymer (ProtoMold 2013). The other constraints affecting the design of the valve included using easily replaceable seal materials, keeping with laws and regulations in place for valves at California dairies, and maintaining a relatively low cost. The majority of pipelines on California dairies are 1 in. galvanized pipe while the float valves are ¾ in. NPT connections. To avoid the need for a reducer by the trough, the new designs were to feature 1 in. NPT inlets.

First Iteration Float Valve Design. The first design iteration considered the possibility that water pushing against the sealing surface of the plunger accelerates the failure of the BOB® valves. In order to resolve this problem, a valve was designed to allow sealing to occur with the assistance of the flow of water through the pipes as seen in Figure 4 and Figure 5. The fixed link between the float and the valve body was rotated 180 degrees to the top of the valve body. This changed the direction of movement for the plunger with regard to the water level in the troughs. The sealing surface for the valve was then moved inward on the valve body, toward the water supply pipes. The seal on the end of the plunger was designed to be smaller than the bore inside of the pipe threads so that when the water flowed through the valve, it would flow around the seal, past the seat, and through the outlet. An o-ring was incorporated into the design to stop backflow past the plunger. The o-ring was a replacement for the skirt seals used on BOB® valves. Solid Works renderings of the model were produced and part drawings can be seen in APPENDIX B: Part Drawings.

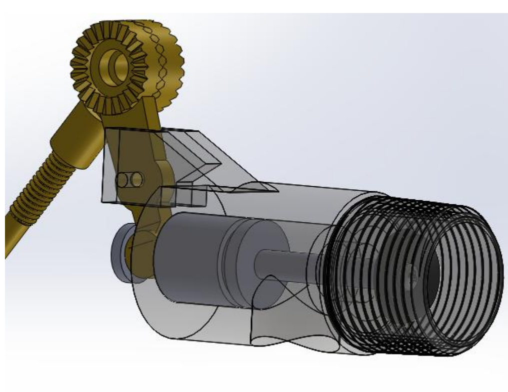

Figure 4. Inverted Valve with transparent valve body.

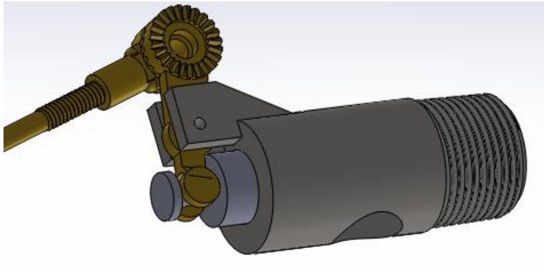

Figure 5. Inverted Valve isometric view.

Second Iteration Float Valve Design. The second design iteration was conceived with the idea that O-Rings are a cheap and simple sealing material for dairymen to replace. A common o-ring size was used for both the main seal and the backflow seal. The direction of movement for this plunger was to be the same as the BOB valves, meaning the float linkage on the valve body remained on the underside of the valve by the water outlet. Due to the simplicity of the design, the inner surface of the valve body remained a constant diameter. This feature would reduce cost for the dairymen because labor becomes significantly less in construction of the valve body. A larger drilled outlet hole was incorporated in the design to allow a larger volume of water to escape once the o-ring passed this surface as seen in Figure 6. The Solid Works renderings of this design can be found in APPENDIX B: Part Drawings.

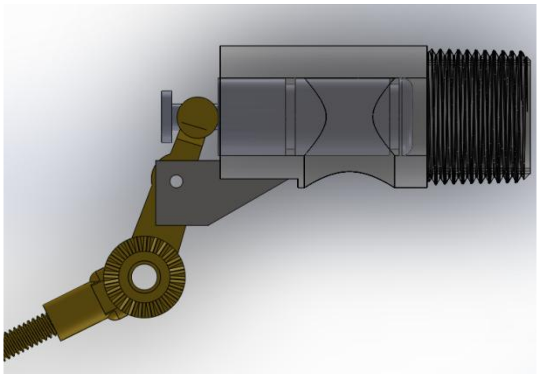

Figure 6. Large Outlet Float Valve transparent view.

Third Iteration Float Valve Design. The third design iteration was very similar to the second. The piston used for the second iteration was not changed and the valve body was almost identical. Rather than using a large outlet hole, several small outlet holes were drilled into the valve body so that the sealing o-ring would not be pushed out of the outlet as seen in Figure 7 and Figure 8. Solid Works drawings can be found in APPENDIX B: Part Drawings.

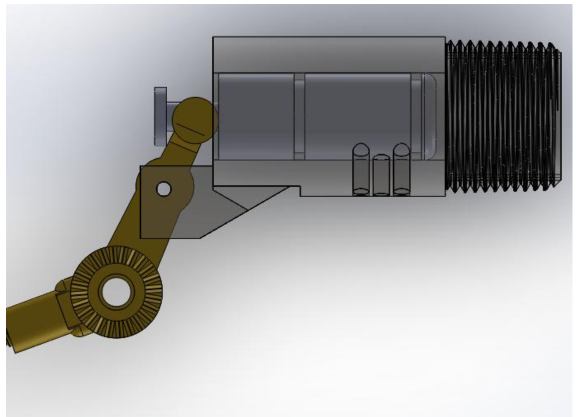

Figure 7. Small Outlets valve transparent view.

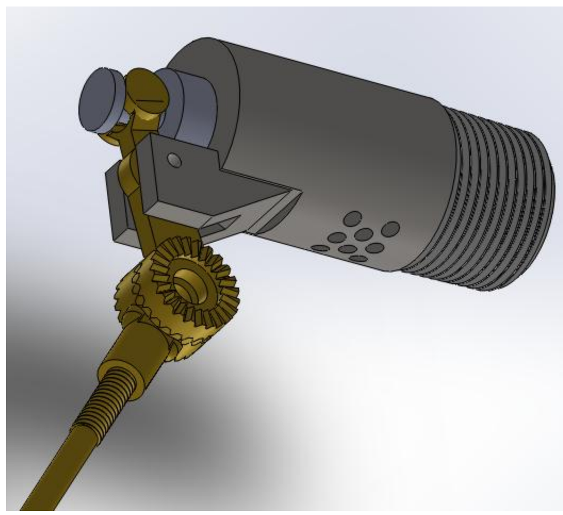

Figure 8. Small Outlets valve isometric view.

Construction Procedure

The first step in valve construction was to cut 1 in. NPT on the 1-3/8 in. black Delrin® rod that was to be used as the valve bodies. Due to the taper on NPT fittings, a manual threader was used to avoid a difficult setup process on the lathe. After cutting threads, the valve bodies were cut to 3 in. lengths using a band saw as seen in Figure 9. These 3 in. pieces were then placed in the lathe with a three jaw chuck to be faced and bored to the proper diameters.

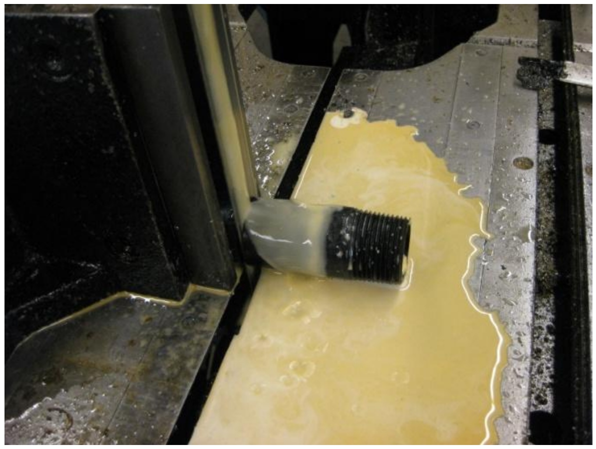

Figure 9. Cutting the threaded valve body in the band saw.

The float valve plungers were constructed from ¾ in. black Delrin® rod. The ¾ in. rod was cut with a band saw to lengths of 5-1/2 in. and each side was faced. A center drill was used to create a divot for the live center to hold the plungers while they were turned as seen in Figure 10. Once one plunger was completed, the 5-1/2 in. section was flipped to allow a second plunger to be constructed before separating the two. The band saw was used to separate the two plungers, and then the plungers were each mounted in the lathe one final time to face the surface that had been cut.

Figure 10. Completed plunger with hole for the live center to support part.

Each of the float valve iterations used the same fixed links. The fixed links were constructed from 5/8 in. square Delrin® rods. The rod was cut in the band saw to lengths of 1-3/32 in. Then the rods were placed in the milling machine and a No. 30 drill bit was used to allow the cotter pins to hold the float linkages in place. The No. 30 holes were drilled 0.200 in. from the bottom and outer edges of the fixed link. Next, the links were rotated so that the linkage slots could be machined. The linkage slots were machined to 0.200 in. wide and 5/8 in. deep. The fixed links were then rotated again to allow an angle to be machined into the linkage slots. This angle was not critical, so the angle was machined by eye. Finally, the fixed link seat was machined to a length of 1.077 in. at a depth of 0.177 in. Rotating the link one last time, the back side angle was machined without any particular precision for aesthetic purposes. On the fixed link seat, a No. 28 drill bit was used to put holes at an approximate depth of 0.10" to allow glue to hold the fixed link to the valve body as seen in Figure 11. The holes were not carefully measured as the location was unimportant to the effectiveness of the fixed link mounting.

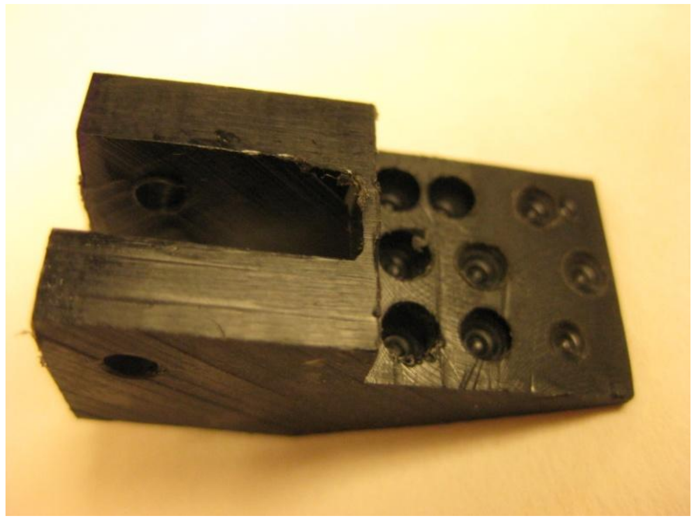

Figure 11. Completed fixed link with holes to allow glue penetration.

<u>First Iteration Float Valve Construction.</u> The 3 in. valve body was mounted in the lathe using a three jaw chuck. Once each side had been faced as seen in Figure 12, a center drill was used to guide drill bits into the valve body. A 9/16 in. bit was run through the entire valve body. After the 9/16 in. hole was drilled, a 23/32 in. bit was driven into the back of the valve a depth of about 1-5/8 in. A boring bar was then used to turn the inside dimension to the proper diameter of ¾ in. at a depth of 1-5/8 in. from the back of the valve body and achieve a smooth surface for the movement of the plunger. Once the main bore had been turned to ¾ in., the inlet side of the valve body was bored to 1 in. inside diameter using a drill bit at a depth of 1 in. into the valve to allow more water to enter the valve body. A drill bit was used, rather than the boring bar, to give the inside edges a chamfer that would allow the Nitrile seal on the plunger to seat properly. Finally the back of the valve bodies received a chamfer using an 82° countersink to allow o-ring to pass by smoothly without binding.

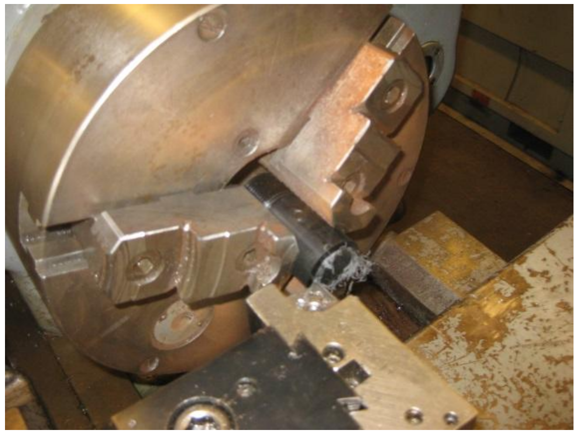

Figure 12. Facing valve bodies.

Following the construction of the valve body, the plungers were turned to the proper dimensions. The plunger was faced and a center drill was used to give the plunger a divot into which the live center could support the chucked piece. The plunger was then turned to smooth the outside edge. The plunger rod was turned down to ¼ in. so that it could allow water to flow around it inside the 9/16 in. hole in the valve body. The ¼ in. section was turned on a length of 1-3/8 in. At that point, the plunger returned to a diameter of ¾ in. An o-ring groove was cut in the plunger a width of 1/8 in. with a diameter of 9/16 in. Finally, the narrow section for the linkage to grab the plunger was turned down to ¼ in. diameter at a length of 0.45 in. For complete construction measurements, see APPENDIX B: Part Drawings.

Finally, a punch press was used to punch out a ¾ in. piece of Nitrile to form the main seal. A large curved washer was placed on top of the seal and a small curved washer underneath so that the seal could seat properly in the valve. A screw was driven through the Nitrile and into the end of the plunger to form the seal.

<u>Second Iteration Float Valve Construction.</u> The 3 in. valve body was again placed in a three jaw chuck and faced. A center drill was used to guide drill bits through the center of the valve body. First, a 7/16 in. drill bit was plunged all of the way through the valve body and then a 23/32 in. bit was plunged through. Next, a boring bar turned the inside diameter to ¾ in. with the lathe spinning at 1000 RPM at a feed rate of 0.0023 in. per revolution. On the inlet side of the valve, the boring bar was used to extend the diameter of the valve to 1 in. at a depth of 1 in. as seen in APPENDIX B: Part Drawings.

The part was then removed from the lathe and a center drill in the milling machine was used to locate the outlet 1-1/4 in. from the back of the valve body and in the center of the valve body. An intermediate bit was used prior to drilling a 7/8 in. hole about ¾ of the way through the valve body. A fixed link platform was then machined on the same side as the outlet hole to a width of 0.67 in. and back from the rear end of the valve body ¾ in.

The plunger was constructed simply with two o-ring grooves: one as a backflow seal and one as the main seal of the valve. Once the outside of the plunger was turned to have a smooth ¾ in surface, and the center drill was used to mount the plunger against a live center, a 1/8 in. wide lathe bit was used to cut the o-ring grooves. The primary seal groove was cut 1/8 in. from the front of the plunger. The second, backflow groove, was cut 1-5/32 in. from the front of the plunger. Each groove was cut so that the diameter of the groove was 9/16 in. After the grooves were turned in the plunger, a fine file was used to achieve a fillet on the front end of the plunger. The radius of the fillet was not critical so the file was used to achieve an aesthetically pleasing finish. The linkage groove in the plunger was cut 1.873 in. from the front of the plunger to a diameter of ¼ in. and for a length of 0.45 in. Finally, the head of the linkage groove was turned to ½ in. diameter at a width of 0.10 in. At this point, the plunger was turned around and the process repeated for a second plunger. After the second plunger was completed, the band saw was used to separate the two plungers and each side that was cut was faced to achieve the proper thickness and a smooth finish. The dimensions and layout of each part can be seen in APPENDIX B: Part Drawings.

<u>Third Iteration Float Valve Construction.</u> The valve body was constructed exactly as the second iteration body in the lathe. The first difference is seen in the outlet holes formed in the milling machine. The part was aligned in the milling machine and small No. 28 dill size holes were used as the outlet. Eight holes were machined so that adequate flow could be achieved. The first row of three holes was located 1.375 in. from the inlet side of the valve body. One hole was located at the center of the part and a hole was placed on either side of this one 0.225 in. away. The next row contained only two holes 1.550 in. from the inlet. These holes were 0.225 in. apart and half that distance from the center of the valve body. The third row imitated the first row, but at a distance of 1.725 in. from the inlet. The same fixed link platform was then machined on the valve body as the second iteration had received. For details of the third iteration valve, see APPENDIX B: Part Drawings. The plunger and the fixed link for the third iteration float valve were the same as the second iteration.

For each of the float valves that were constructed, the fixed links were connected to the valve bodies using JB Weld. Eventually, the JB Weld was abandoned and a hot soldering iron was used to weld the fixed link to the valve body as seen in Figure 13.

Figure 13. Fixed link plastic welded to valve body.

<u>Testing Procedure</u>

A female hose end was connected with a short piece of hose and a 1 in. female NPT end so that the valves could be tested off of a standard faucet. Each valve was placed in the testing apparatus seen in Figure 14 and cycled several times to determine the function of the valves. Successful valves were implemented on a dairy for long term testing in the actual environment.

Figure 14. Testing apparatus in use.

In order to determine the flow rates at several pressures, a Schrader valve was installed in the testing apparatus upstream of the float valves. A pressure gage was used to observe the pressure as a 5 gallon container was filled. The time to fill the 5 gallon container was recorded and from this value, a flow rate at each pressure tested was determined.

RESULTS

The first iteration design, using water pressure to assist in sealing the valve closed, functioned properly when a heavy float was used, or a long float arm. The completed valve can be seen in Figure 15 below. The valve had a large wide open flow rate and it sealed very well; however, when the valve was close to closing, the water would push the valve closed the remainder of the way with extreme force causing water hammer in the inlet pipes. It also took a significant amount of force to re-open the valve once it was closed as it had to push against water pressure.

Figure 15. Completed first iteration float valve.

The second iteration float valve using an o-ring to seal and prevent back pressure with a large outlet hole did not function properly during testing. This completed float valve can be seen in Figure 16.

Figure 16. Second iteration float valve completed.

Figure 17 shows the completed third iteration float valve. The plunger was able to slide freely past the small holes and create a good seal. When the float valve was opened, the water flowed at a good rate for keeping a water trough full.

Figure 17. Third iteration float valve completed.

The J-B Weld that connected the fixed link to the valve body failed at low stresses. With an ideal bond, J-B Weld has a tensile strength of 3960 psi. When bonding plastics together, it is likely that the bond would not be ideal so the J-B Weld would fail at a far lower stress than 3960 psi. Delrin® Acetal Resin has a tensile strength of 10,000 psi and shear strength of 9500 psi (DuPont 2013). Using plastic welding to connect the fixed link to the valve body may not provide the maximum strength of Delrin®; however, the strength of the fixed link would be far higher than the strength of J-B Weld. Once the fixed links were fused to the valve body by melting the two together, the link could handle much higher stresses. In a mass production setting, using injection molding, the fixed link would have the full tensile strength of the material.

After testing the third iteration float valve, a graph was made showing the flow rate when the valve was fully open compared to the pressure in the pipeline as shown in Figure 18.

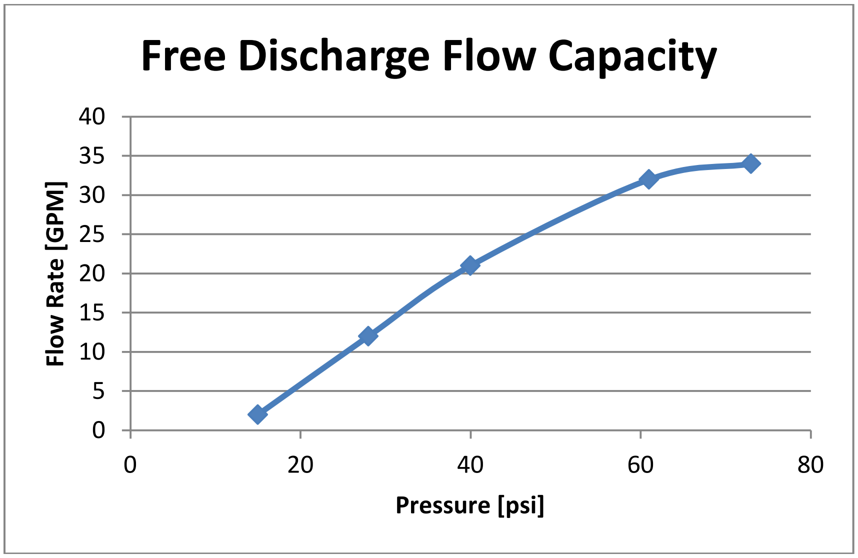

Figure 18. 3rd iteration float valve free discharge flow capacity.

DISCUSSION

The first iteration float valve was conceived with the idea that using water pressure to help seal would allow the valve to last longer without replacing the seal materials. The valve would open and close causing a good flow rate when open and a tight seal while closed; however once the valve was closed, a significant force was needed to re-open the valve. A heavy float was used to allow the valve to open, yet, when the valve was close to shut the water pressure would force the plunger back into its seat quickly causing water hammer. It was determined that this water hammer was great enough to discontinue the use of the valve as it may cause permanent damage to the pipes on the dairy.

The second iteration float valve, using o-rings as the main and backflow seal and a large outlet hole, failed to seal properly. The backflow o-ring worked well while the sealing o-ring would get pushed out of the outlet hole causing a poor seal. Several attempts were made to give the valve a consistent sealing area, but the efforts were fruitless in stopping the o-ring from pushing out. This led to the design and construction of the third iteration float valve.

The third iteration float valve used the same plunger as the second iteration valve with small openings for the outlet and this valve functioned properly. Each side of the valves can be seen in Figure 19. A flow rate around 30 GPM was achieved by the third iteration valve while the water level was down and the valve sealed properly when the trough was full as seen in Figure 20. The valves were installed at a heifer ranch in Hanford, CA run by Jimmy Goebel as seen in Figure 21. Several of the valves with JB Weld to hold the fixed link to the valve body have failed; however, it is expected that when the two are fused together there will be no issue.

Figure 19. Third iteration valves, four views.

Figure 20. 30 GPM while open and good seal while closed.

Figure 21. Third iteration float valves supplying water to the heifer ranch troughs.

The approximate cost per third iteration float valve is $3.75 for strictly materials. During construction many small design and manufacturing techniques were altered causing time of production and wasted material to be high. In strictly producing third iteration valves as shown in APPENDIX B: Part Drawings, the time to construct one valve is approximately 2 hours. At a billing rate of $25 per hour, this makes the cost per valve round to about $55. This is a bit more than the price of the BOB® valves due to use of precision manufacturing techniques such as machining and turning the parts. If injection molding was used for production of the float valves, the cost of production could be greatly reduced causing the valves to be desirable for dairymen and possibly preferable to the brass valves.

RECOMMENDATIONS

At the conclusion of testing and evaluating the Delrin® float valves, it was determined that a superior method of attaching the fixed link to the valve body is necessary to continue with implementation of the product. If these valves were to be mass produced, injection molding would likely be used which would solve the problem.

The first and second iteration designs have likely not been used in the past for systemic reasons. The first iteration caused significant water hammer which could not be reduced in keeping the design similar without added complexity and cost. The second iteration design was based on poor o-ring design as o-rings are not meant to travel across large openings. These designs should not be pursued in the future.

The third iteration design was fairly successful. If continued, it may be necessary to avoid the repetitive contact of the o-ring with the small outlet holes. The wear against these small holes may cause damage to the o-rings over time; however, if the o-rings last about as long as the BOB® valves, then the risk becomes insignificant due to the lower cost of replacing simple o-rings.

When attempting to thread the 1-3/8 in. pipe, it was determined that the pipe was larger than what is typically used. 1-1/4 in. pipe should be used in continuation of the project. Also, the manual pipe threader was not the ideal tool to use for cutting threads on Delrin® because the material would compress in the threader. This caused a tight fit for the valves in the female pipe thread fittings. In the future, time should be taken to set up a lathe to cut the threads for plastics.

Finally, when producing the float valves manually, the cost including time becomes very similar to the brass float valves. In a mass production setting, it would be vital to speed up production by using injection molds and simply cleaning up surfaces using precision tooling.

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APPENDIX A: BRAE Requirements

How Project Meets Requirements for the BRAE Major

Major Design Experience – The project must incorporate a major design experience. Design is the process of devising a system, component, or process to meet specific needs. The design process typically includes the following fundamental elements. Explain how this project will address these issues. (Insert N/A for any item not applicable to this project.)

Establishment of objectives and criteria	Objectives and criteria of this project include maintaining or lowering the cost of the current standard float valve, improving long term performance of the float valve, and increasing customer satisfaction
Synthesis and Analysis	The plastic float valve will achieve proper flow rates to keep troughs full of water.
Construction, testing, and evaluation	The plastic valve will be designed, constructed, tested, and evaluated.
Incorporation of applicable engineering standards	The project will utilize ASTM standards for the Delrin strength.

Capstone Design Experience – The engineering design project must be based on the knowledge and skills acquired in earlier coursework (Major, Support and/or GE courses.)

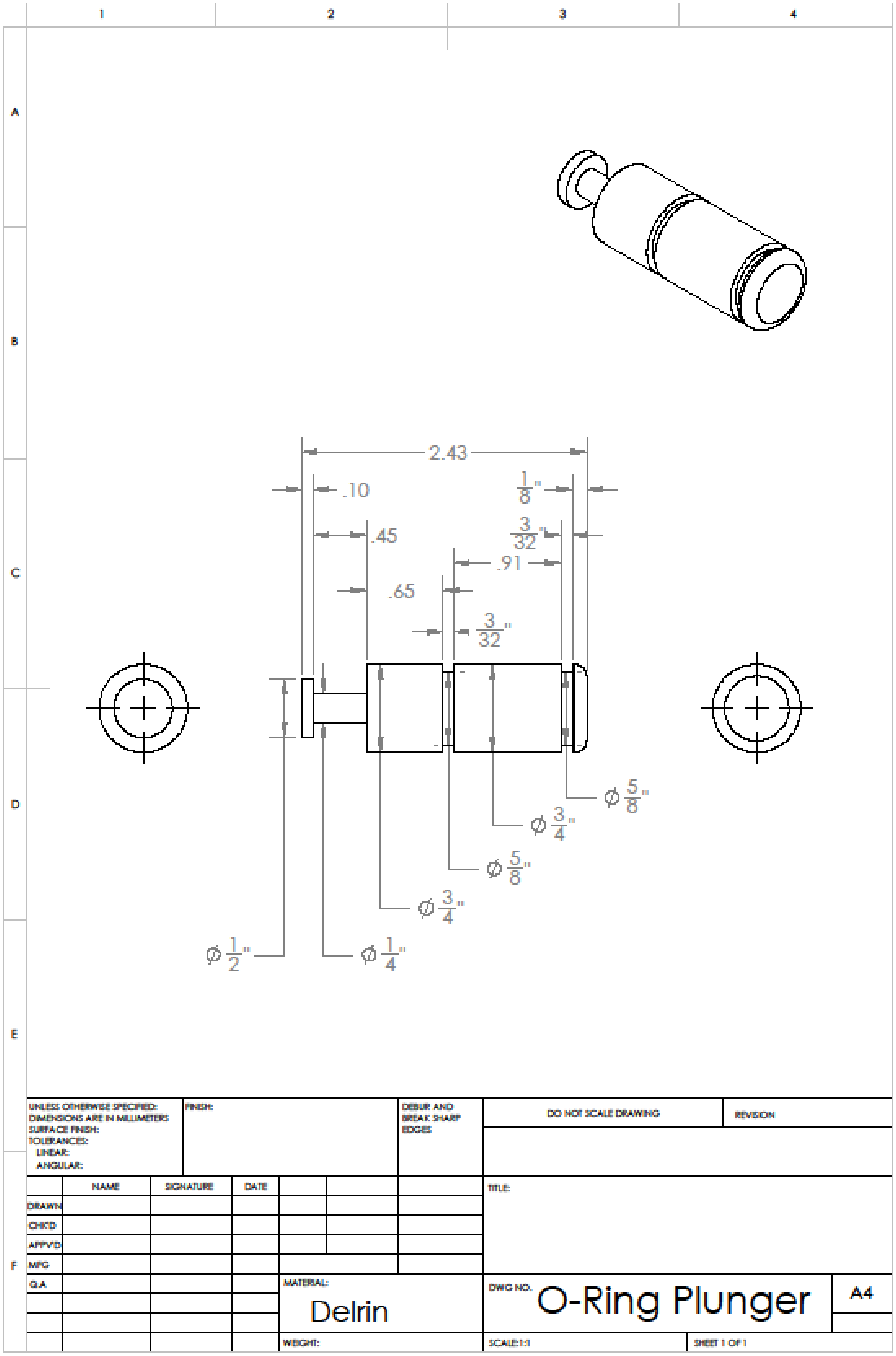
Incorporates knowledge/ skills from these key courses	129 Lab Skills/Safety, 133 Engineering Graphics, 151 AutoCAD, 152 SolidWorks, 312 Hydraulics, Engineering Statics, Strength of Materials, Technical Writing

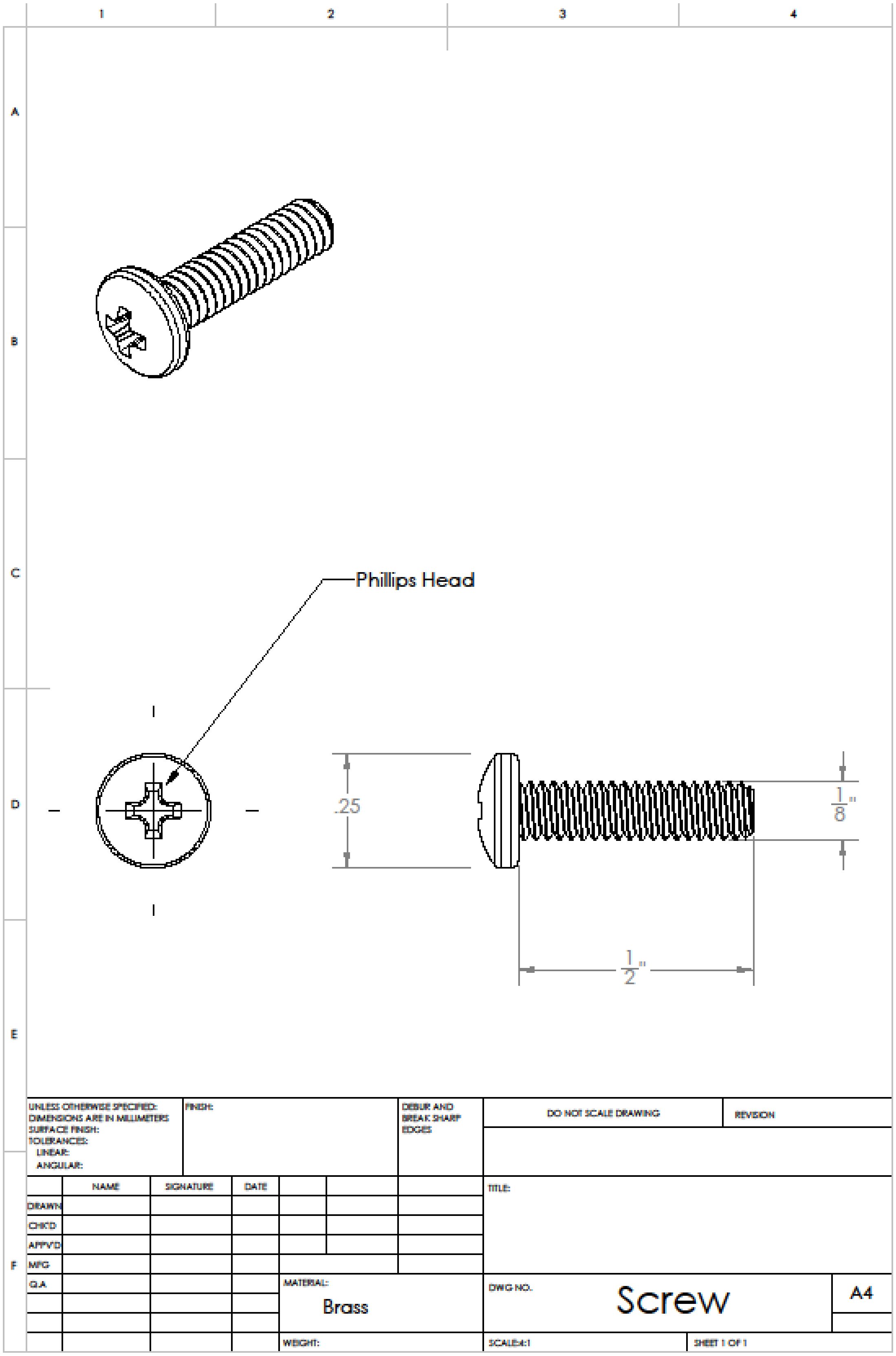
Design Parameters and Constraints – The project should address a significant number of the categories of constraints listed below. (insert N/A for any area not applicable to this project.)

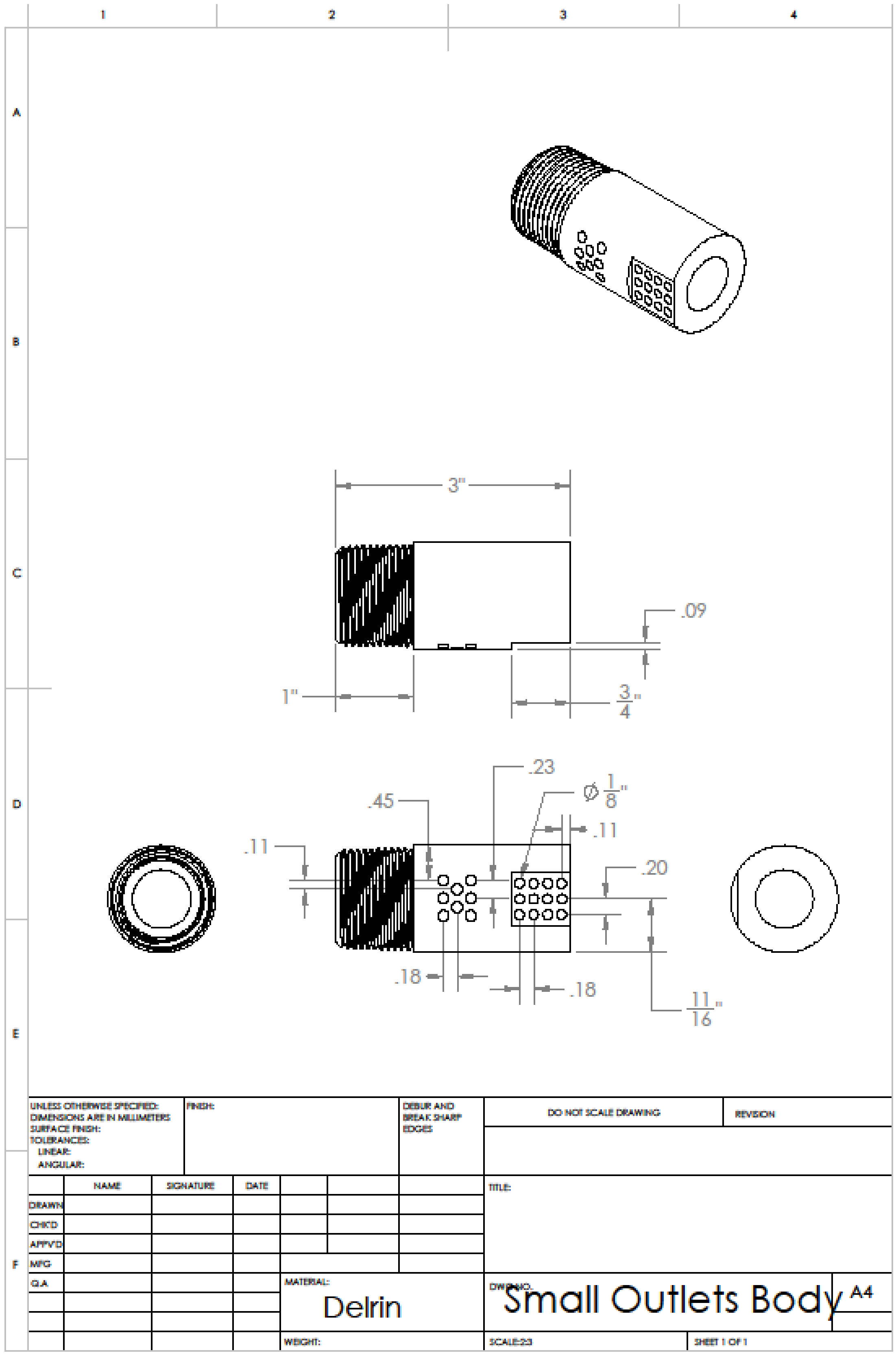
Physical	The valve must have male ends, 90 degrees apart with one inch NPT. The float ball will be on a 10 inch rod.
Economic	The cost of the plastic valve should be much cheaper than the currently available brass valves.
Environmental	The plastic valves will not pollute the water with minerals found to leach from brass. Also, the plastic valves should last longer causing less waste.
Sustainability	The plastic valve will not seize or leak saving water in a part of California where water is scarce.
Manufacturability	The valves for this project are to be machined for simplicity and lower cost for individual product production. Pending success of the project, the plastic valve could eventually be cast for a quick, consistent, cost effective solution.
Health and Safety	Brass is known to leach minerals into water at a fairly neutral pH. The plastic float valve will provide safer water.
Ethical	The plastic valve will not breach any patents and it will remain dissimilar to the styles of currently available float valves

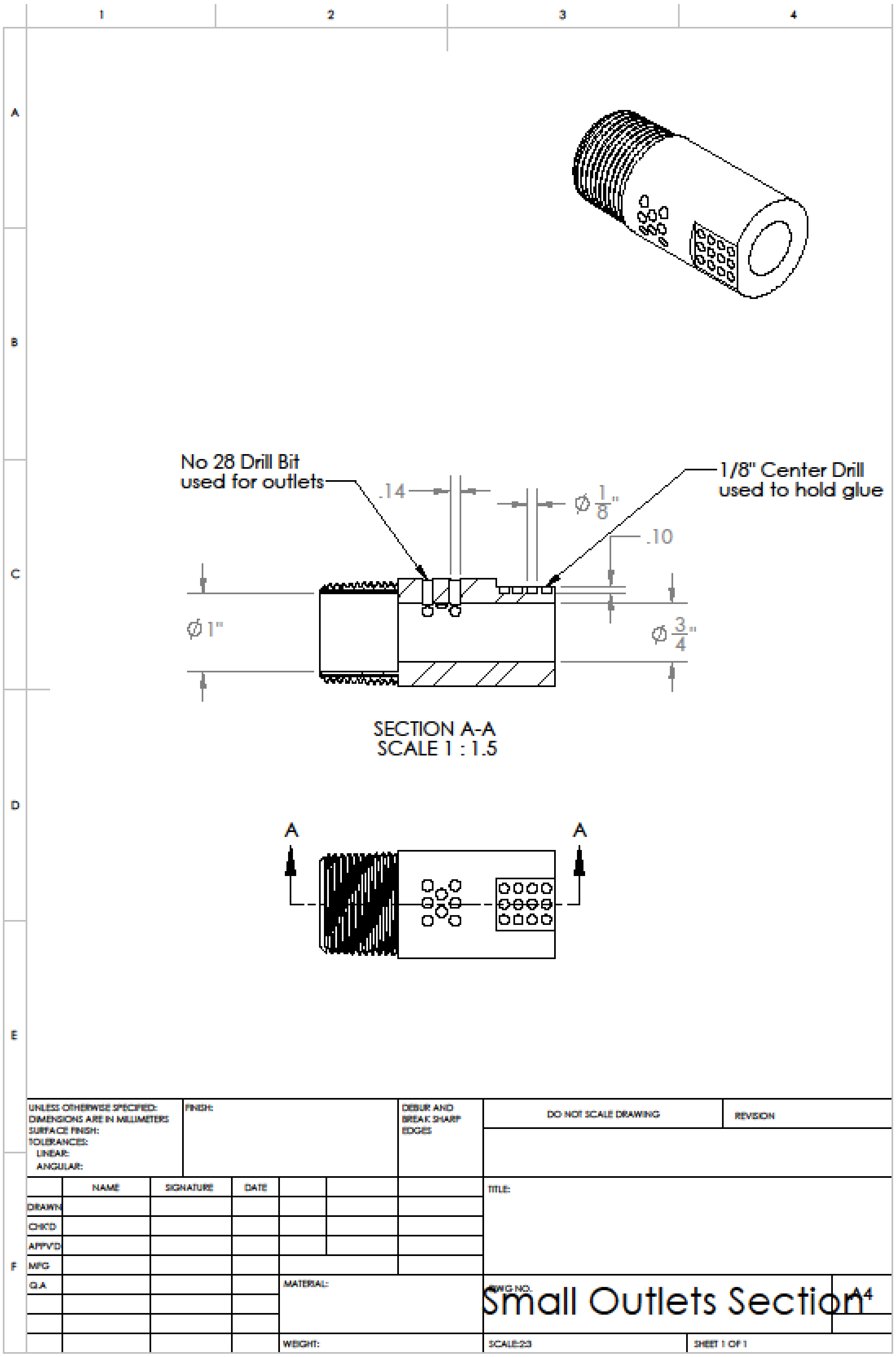
Social	N/A
Political	Water saving.
Aesthetic	The finished float valve will be clean black Delrin with a smooth finish
Other	

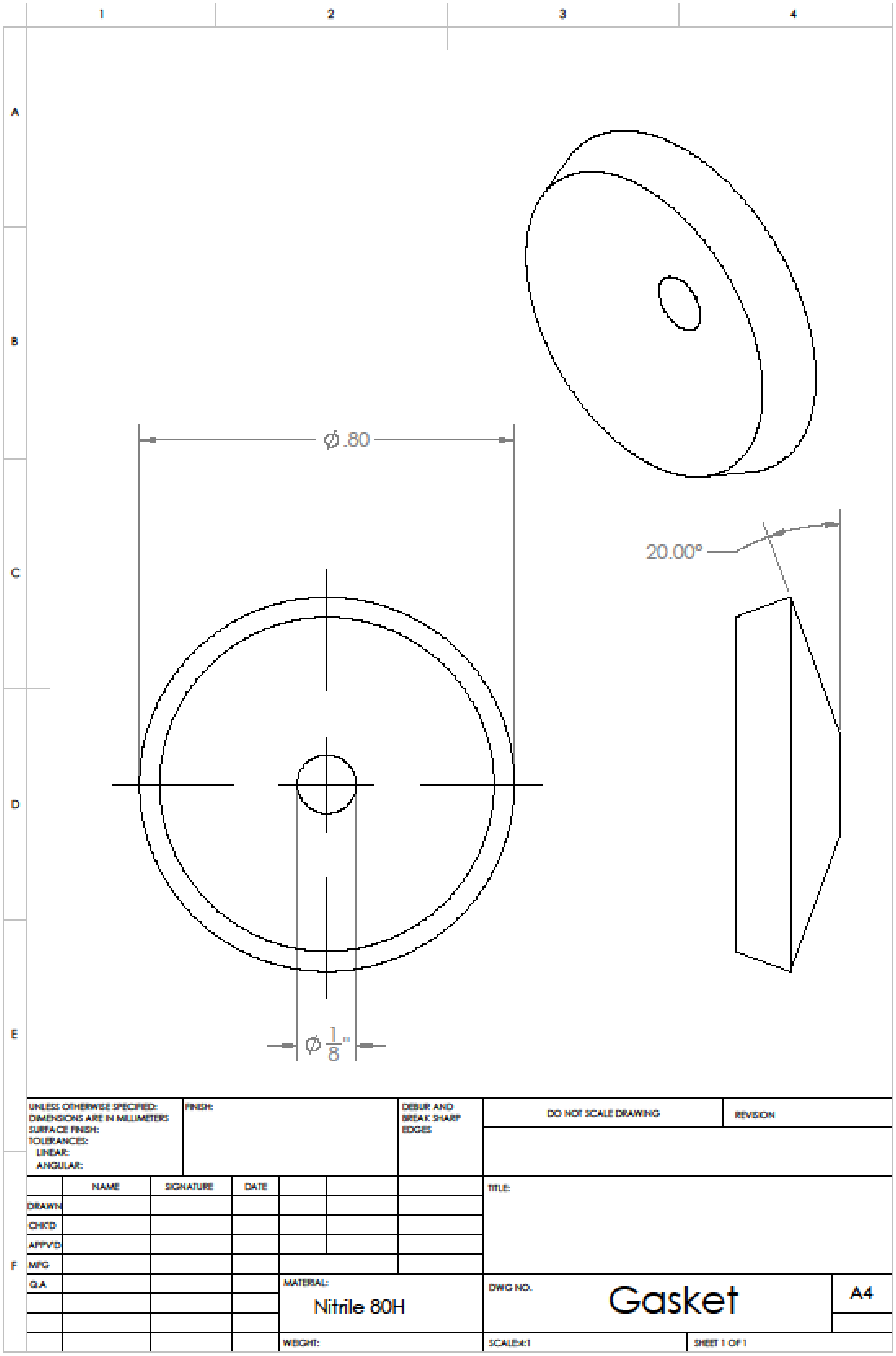
APPENDIX B: Part Drawings


2.43
.10
.45
.65
.91
1/8"
3/32"
3/32"
Ø 5/8"
Ø 3/4"
Ø 5/8"
Ø 3/4"
Ø 1/2"
Ø 1/4"
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBUR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
MATERIAL:
Delrin
DWG NO.
O-Ring Plunger
A4
WEIGHT:
SCALE:1:1
SHEET 1 OF 1

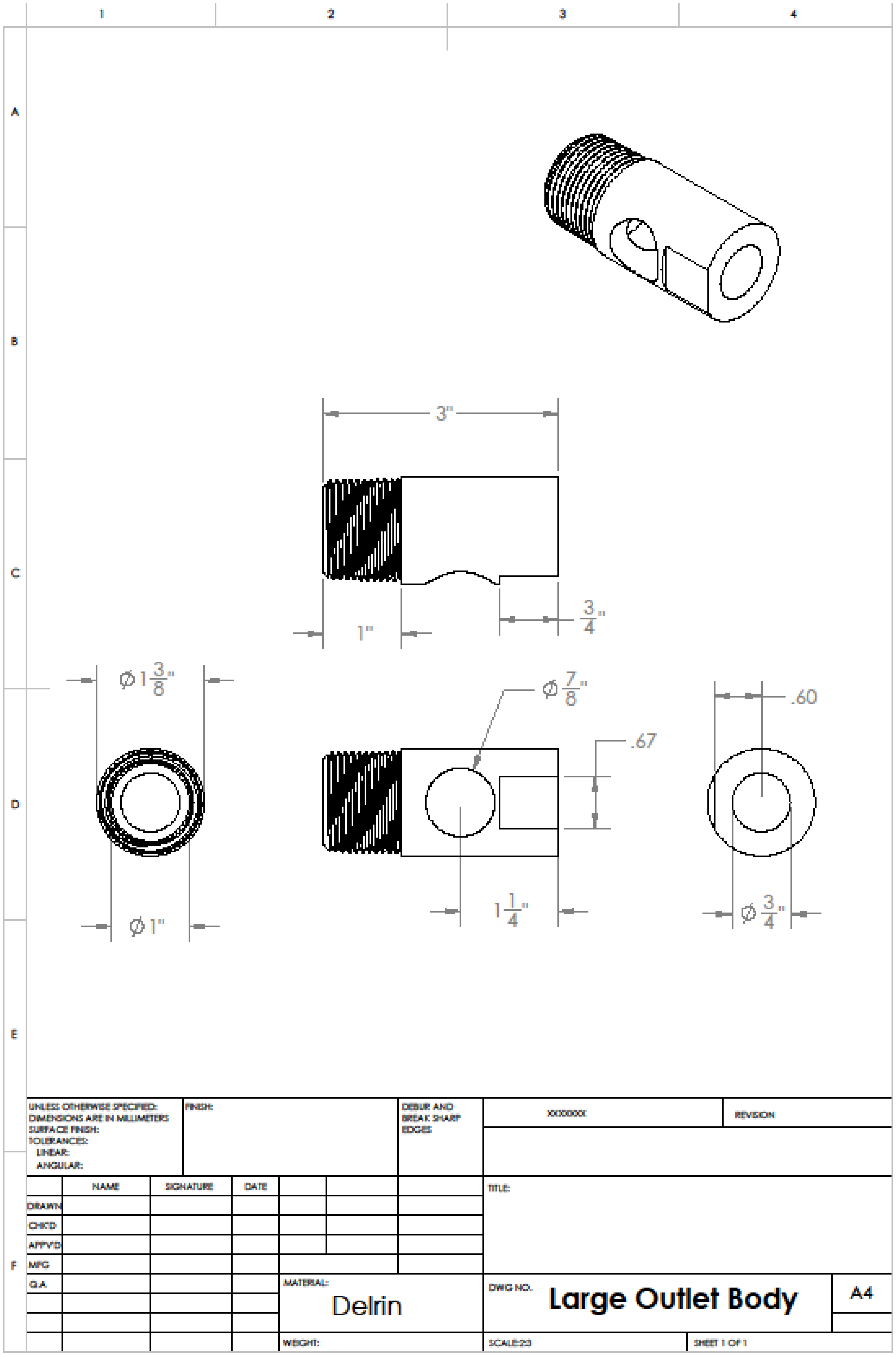

Phillips Head
.25
1/8"
1/2"
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBUR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
MATERIAL:
Brass
DWG NO.
Screw
A4
WEIGHT:
SCALE:4:1
SHEET 1 OF 1


3"
.09
1"
3/4"
.23
ø 1/8"
.45
.11
.11
.20
.18
.18
11/16"
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBUR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
MATERIAL:
Delrin
DWG NO.
Small Outlets Body
A4
WEIGHT:
SCALE:2:3
SHEET 1 OF 1

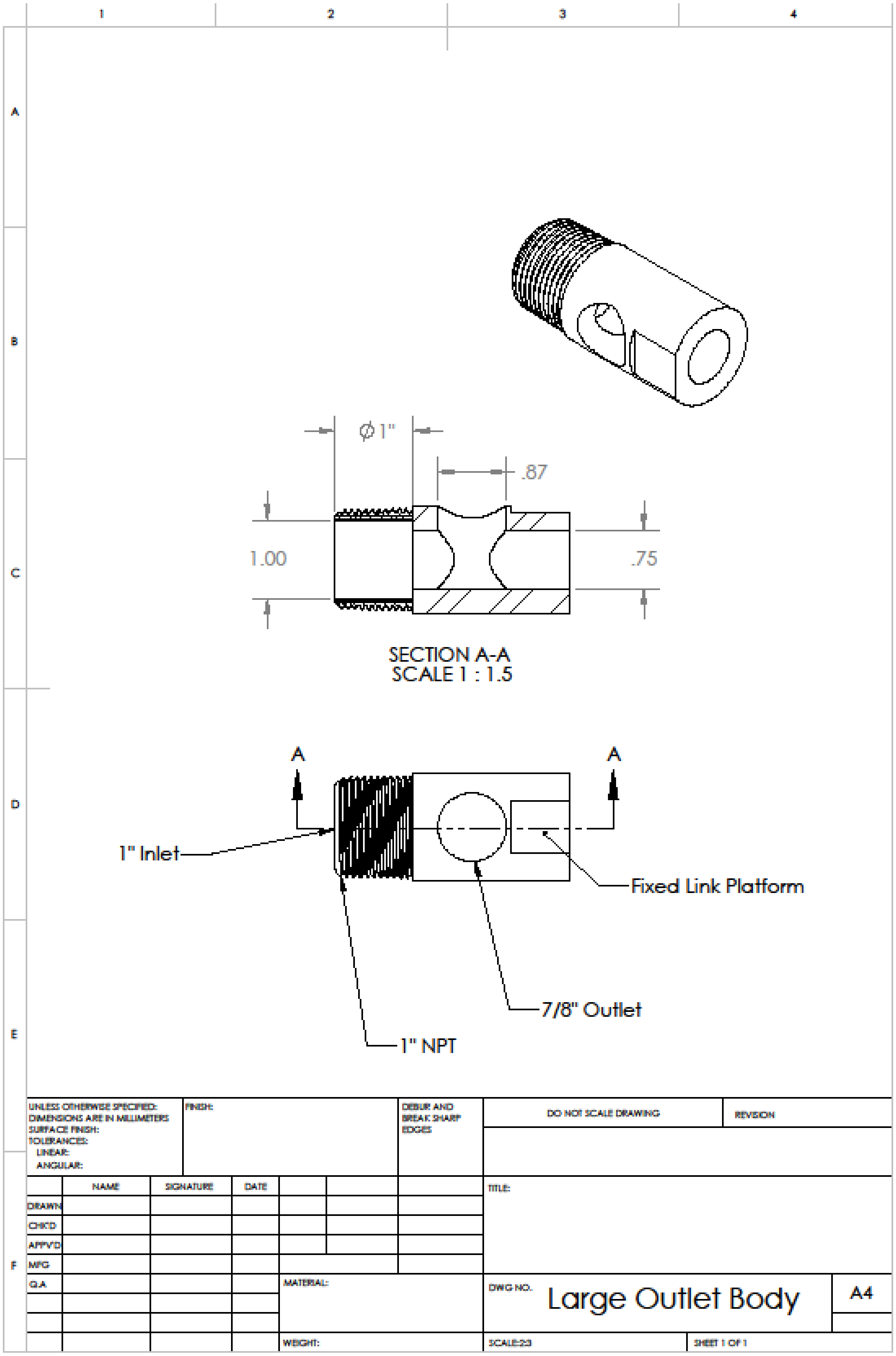

No 28 Drill Bit
used for outlets
.14
$\varnothing \frac{1}{8}$"
1/8" Center Drill
used to hold glue
.10
$\varnothing$ 1"
$\varnothing \frac{3}{4}$"
SECTION A-A
SCALE 1 : 1.5
A
A
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBUR AND
BREAK SHARP
EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
Small Outlets Section
A4
SCALE:2:3
SHEET 1 OF 1

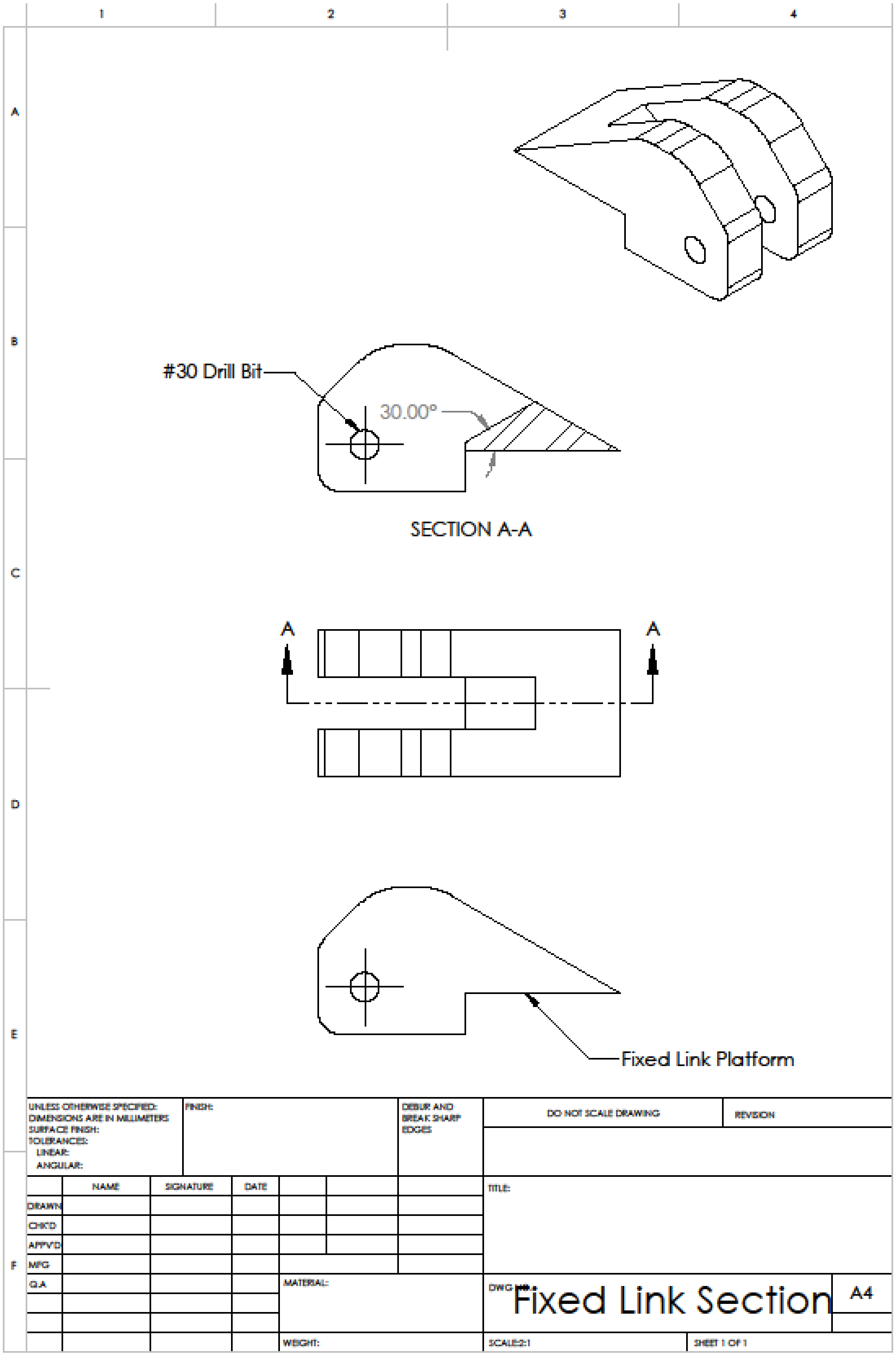


Ø .80
20.00°
Ø 1/8"
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBUR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
MATERIAL:
Nitrile 80H
DWG NO.
Gasket
A4
WEIGHT:
SCALE:4:1
SHEET 1 OF 1

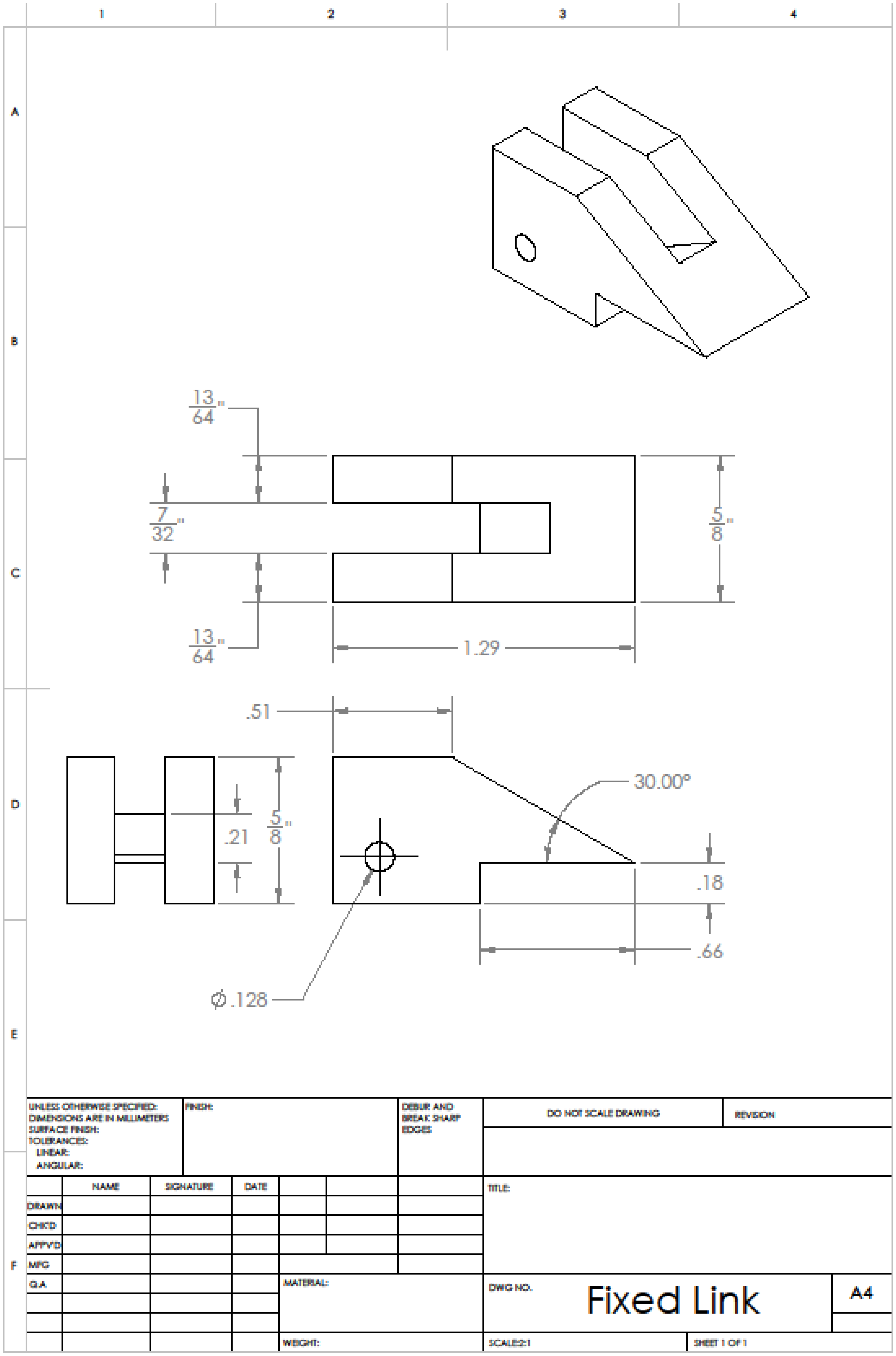


3"
1"
3/4"
Ø 1 3/8"
Ø 1"
Ø 7/8"
.67
1 1/4"
.60
Ø 3/4"
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBUR AND BREAK SHARP EDGES
XXXXXXX
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
MATERIAL:
Delrin
DWG NO.
Large Outlet Body
A4
WEIGHT:
SCALE:2:3
SHEET 1 OF 1

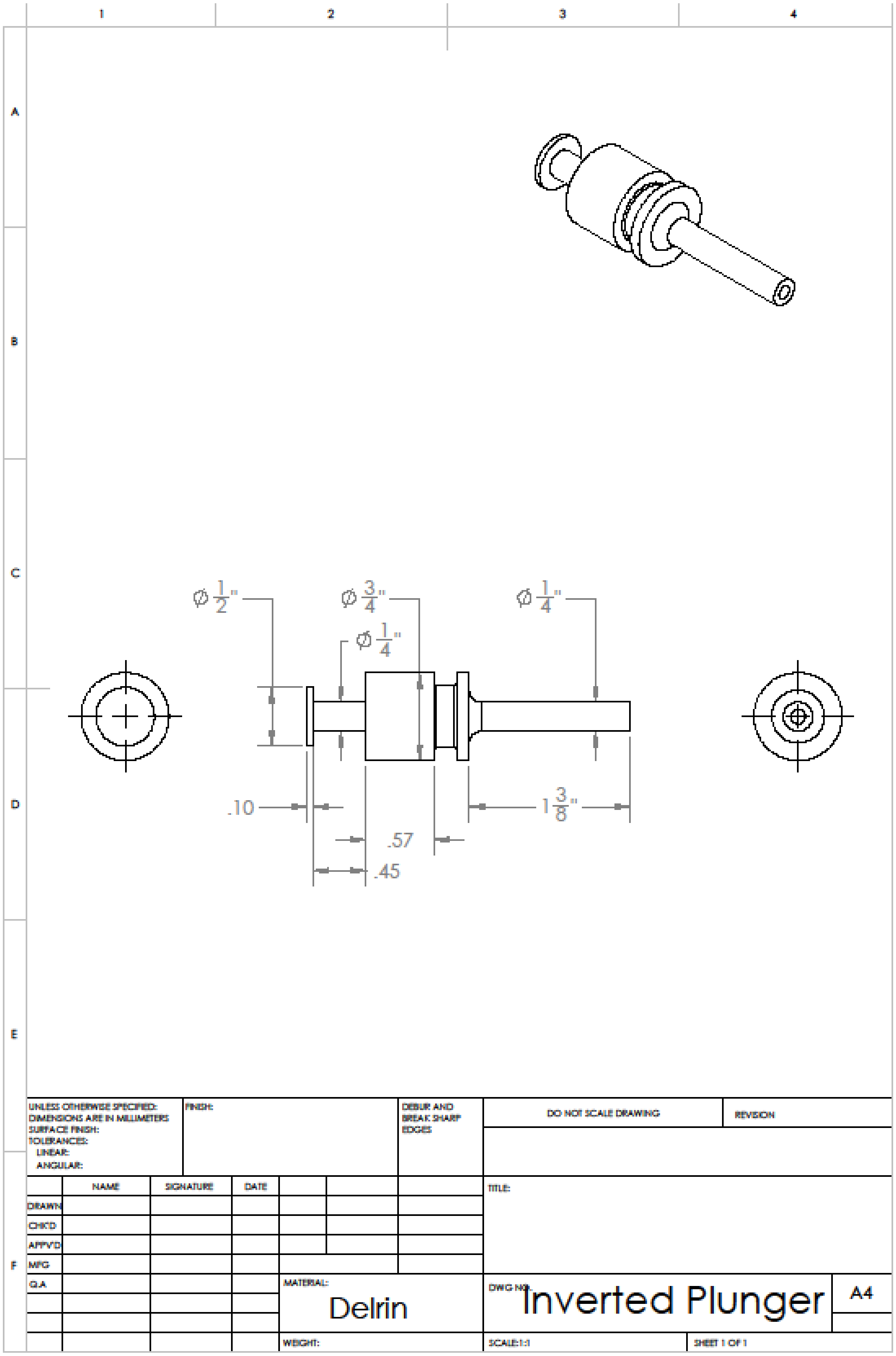

Ø1"
.87
1.00
.75
SECTION A-A
SCALE 1 : 1.5
A
A
1" Inlet
Fixed Link Platform
7/8" Outlet
1" NPT
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBUR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
Large Outlet Body
A4
SCALE:2:3
SHEET 1 OF 1



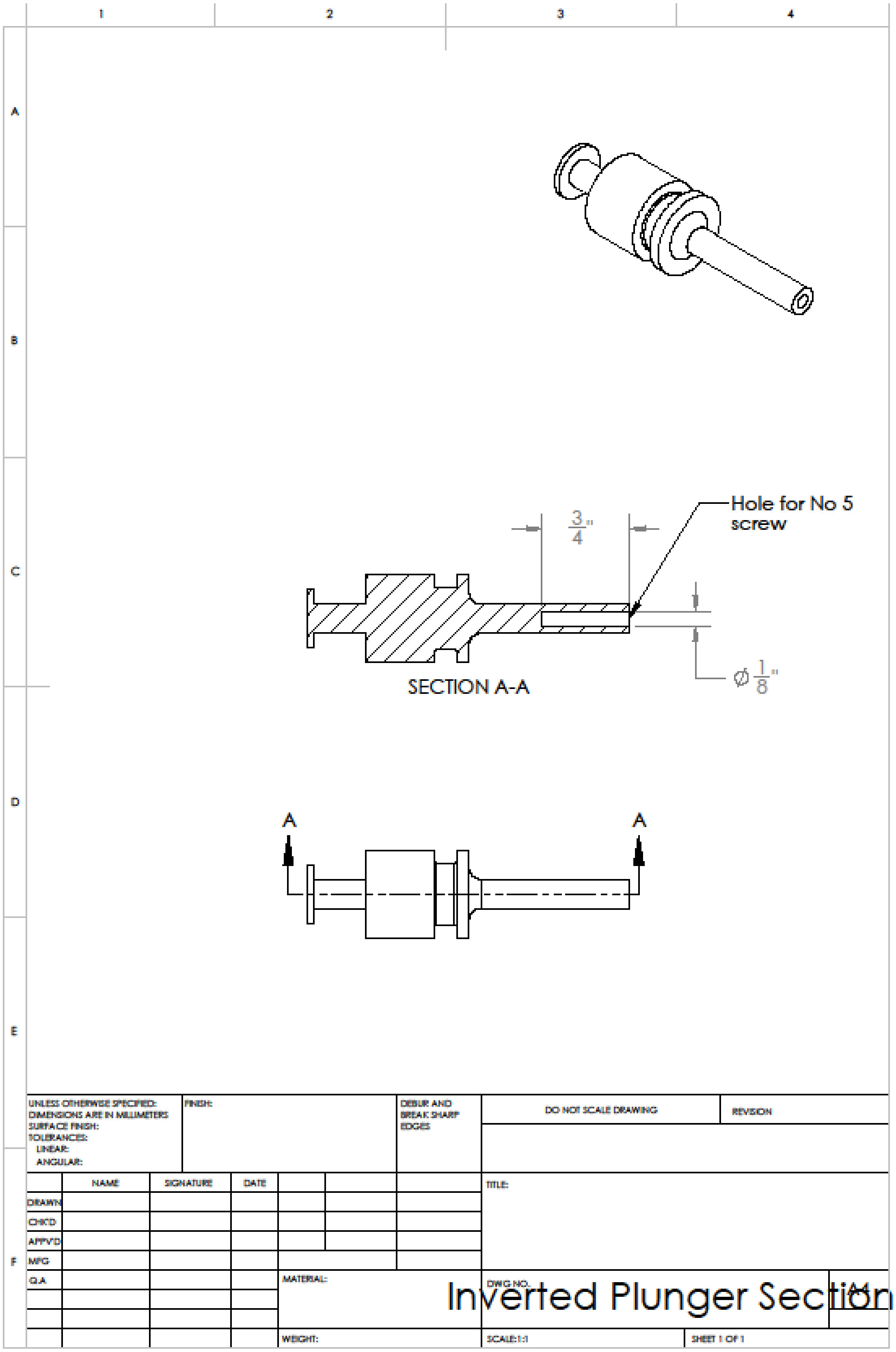
1
2
3
4
A
B
C
D
E
F
#30 Drill Bit
30.00°
SECTION A-A
A
A
Fixed Link Platform
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBUR AND
BREAK SHARP
EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
Fixed Link Section
A4
SCALE:2:1
SHEET 1 OF 1



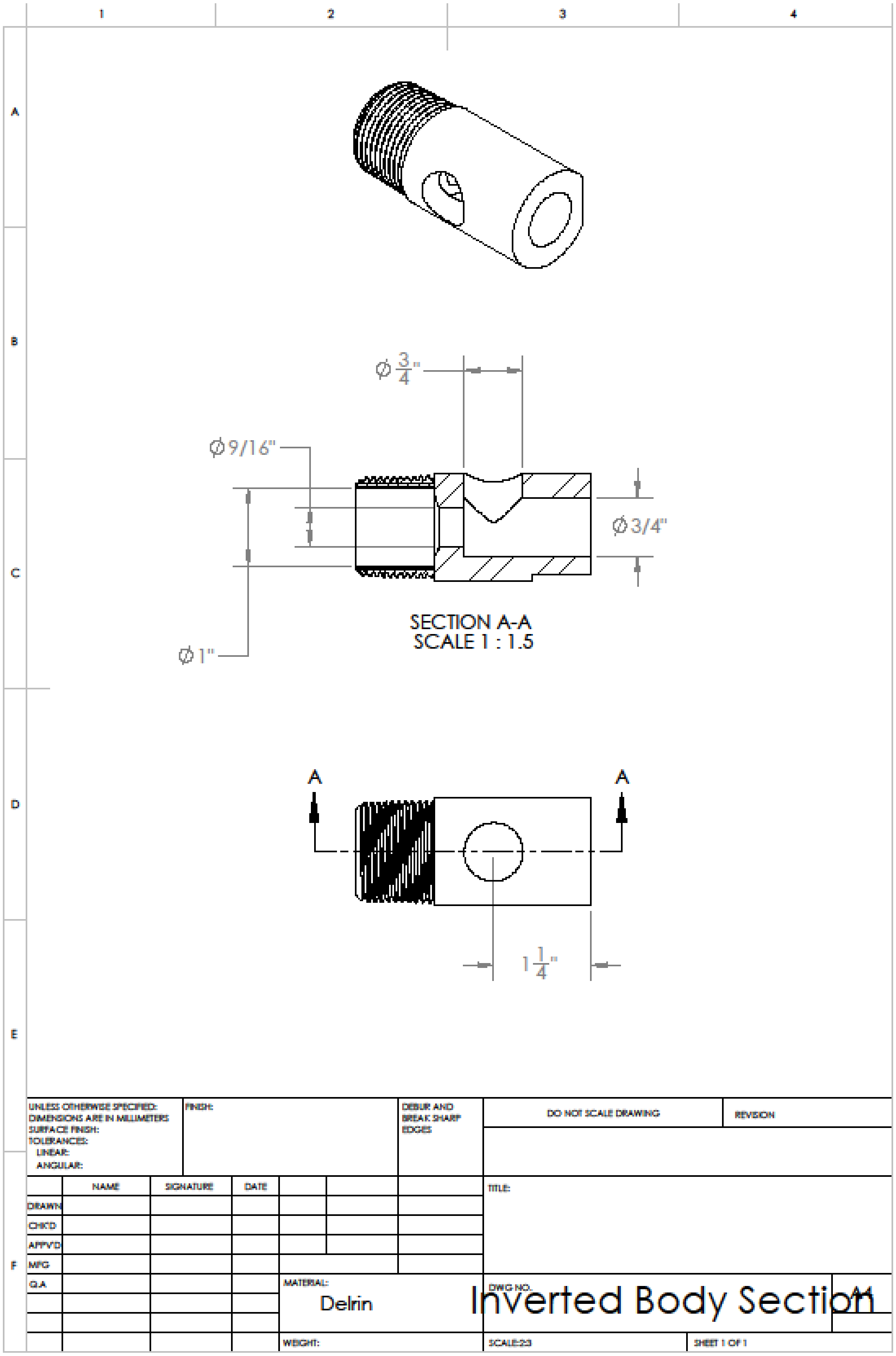
13/64"
7/32"
13/64"
5/8"
1.29
.51
30.00°
.21
5/8"
.18
.66
Ø.128
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBUR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
Fixed Link
A4
SCALE:2:1
SHEET 1 OF 1



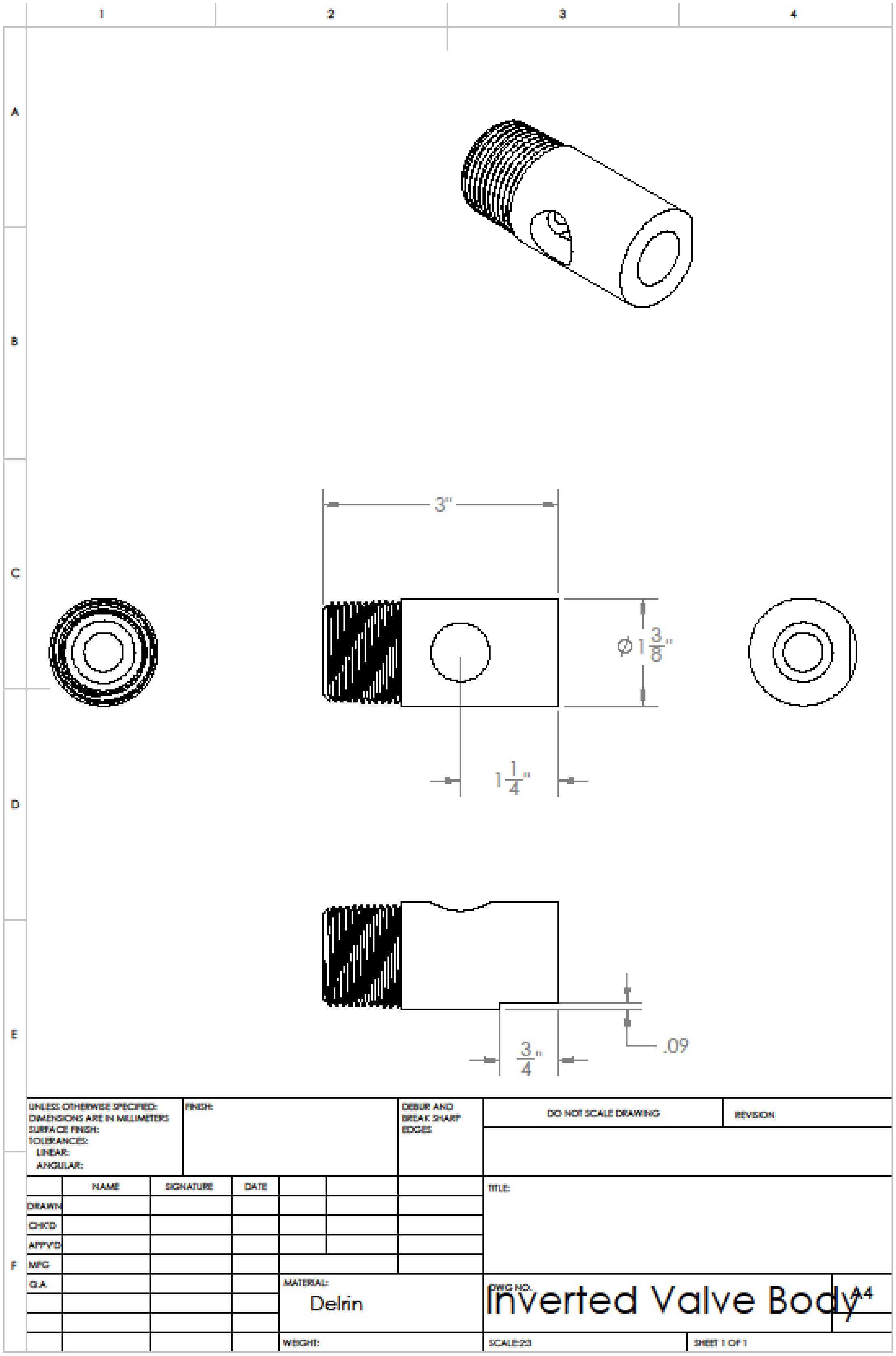
Ø 1/2"
Ø 3/4"
Ø 1/4"
Ø 1/4"
.10
.57
.45
1 3/8"
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBUR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
MATERIAL:
Delrin
DWG NO.
Inverted Plunger
A4
WEIGHT:
SCALE:1:1
SHEET 1 OF 1



1
2
3
4
A
B
C
D
E
F
Hole for No 5 screw
3/4"
Ø 1/8"
SECTION A-A
A
A
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBUR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
MATERIAL:
DWG NO.
Inverted Plunger Section
WEIGHT:
SCALE:1:1
SHEET 1 OF 1



Ø 3/4"
Ø 9/16"
Ø 3/4"
Ø 1"
SECTION A-A
SCALE 1 : 1.5
A
A
1 1/4"
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBUR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
TITLE:
DRAWN
CHK'D
APPV'D
MFG
Q.A
MATERIAL:
Delrin
DWG NO.
Inverted Body Section
A4
WEIGHT:
SCALE:2:3
SHEET 1 OF 1



3"
⌀ 1 3/8"
1 1/4"
3/4"
.09
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBUR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APPV'D
MFG
Q.A
TITLE:
MATERIAL:
Delrin
DWG NO.
Inverted Valve Body
A4
WEIGHT:
SCALE:2:3
SHEET 1 OF 1